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Human Facial Recognition in Holstein Heifers

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HUMAN FACIAL RECOGNITION IN HOLSTEIN HEIFERS

by Kendra Huth

A Thesis Submitted in Partial Fulfillment
of the Requirements for a Degree with Honors
(Animal and Veterinary Sciences)

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ABSTRACT

Cattle see things differently than humans, but it is known that cattle can identify humans based on past encounters. For this study, I hypothesized that Holstein heifers are capable of differentiating between humans solely based on facial characteristics. Six Holstein heifers from J.F. Witter Teaching and Research Farm were trained and tested for 4 weeks using pictures of objects and faces, which the cattle have never seen. A fifth week of testing took place 6 weeks later to examine their long-term memory. Each heifer participated in 10 trials per day using a Y-maze configuration, with 2 photo options to choose from. The heifer received approximately 1/2 cup of sweet calf grain from the bowl if they chose correctly. Week 1 compared a blank, white paper and Caucasian face. Week 2 compared a tree trunk and Caucasian face. Weeks 3–5 compared the African American and Caucasian faces. At the beginning of each session, the correct picture was illuminated with a portable light to help the heifers focus. Data was analyzed with IBM SPSS statistical software, using Chi square procedures to compare the correct choices by heifer, week, and presence of light. Results showed that the heifers' choices improved significantly by week ($p = .007$) and with the use of the light ($p = .013$). The percent correct varied greatly between heifers, ranging from 50% to 80%. One heifer often displayed an 80% success rate with and without the light, supporting the hypothesis. This suggests that Holstein heifers can differentiate between human faces, but it depends on their individual focus levels.

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TABLE OF CONTENTS

INTRODUCTION.....	1
Cow Psychology.....	1
Past Studies.....	2
METHODOLOGY.....	6
The Physical Setup.....	6
Determining Choices.....	10
Data Analysis.....	11
RESULTS.....	12
Combined Data.....	12
Individual Data.....	14
DISCUSSION & CONCLUSIONS.....	22
BIBLIOGRAPHY.....	31
APPENDIX.....	33
Copy of Institutional Animal Care and Use Committee (IACUC) Approval Email....	33
AUTHOR’S BIOGRAPHY.....	34

LIST OF FIGURES

Figure 1. Y–maze Setup.....	9
Figure 2. Pictures.....	9
Figure 3. Total Correct vs. Incorrect Trials for All Heifers Per Week.....	12
Figure 4. Total Correct vs. Incorrect Trials Without Light Per Week.....	13
Figure 5. Total Correct vs. Incorrect Trials With Light Per Week.....	14
Figure 6. Total Correct vs. Incorrect Trials Per Week for Bairn.....	15
Figure 7. Total Correct vs. Incorrect Trials Per Week for Rampart.....	16
Figure 8. Total Correct vs. Incorrect Trials Per Week for Madeline.....	17
Figure 9. Total Correct vs. Incorrect Trials Per Week for Dasahlia.....	18
Figure 10. Total Correct vs. Incorrect Trials Per Week for Ninja.....	19
Figure 11. Total Correct vs. Incorrect Trials Per Week for Riley.....	20

INTRODUCTION

Cow Psychology

The dominant sense for cows is their vision, which allows them to more clearly see different long wavelength colors—red, orange, yellow—compared to short ones—blue and green (Adamczyk et al., 2015 as cited in Marino and Allen, 2017). This is due to them being dichromatic, meaning they have two color receptors unlike humans, who are trichromatic, meaning they have three color receptors. Cows have poor depth perception, which is why they prefer to avoid walking over shadows since they cannot tell if it is a hole in the ground (Ag-Safety, 2019). Additionally, since cows are prey animals, they are more attentive towards things that are moving rather than staying still (Adamczyk et al., 2015 as cited in Marino and Allen, 2017). Another strong sense that cows possess is their sense of smell due to their possession of a vomeronasal organ (Marino and Allen, 2017) and they are capable of smelling things for up to six miles away (Oakley, 2015).

Cows have the capacity to learn quickly within a week of repetitive daily testing and in one study, their long-term memory proved to be existent when 77% of the participating cows retained their learning after six weeks of no testing (Kovalčik & Kovalčik, 1986). This study also supported that heifers—which were fifteen months old in the study—have a much better and faster learning ability than cows, but that cows have a better memory than heifers (Kovalčik & Kovalčik, 1986). Cows also have the capacity to discriminate between different colors (Gilbert & Arave, 1985 as cited in Marino and Allen, 2017), shapes (Baldwin, 1981; Rehkämper & Görlach, 1997 as cited in Marino and Allen, 2017), and brightness (Schaeffer & Sikes, 1970 as cited in Marino and Allen, 2017). Furthermore, cows possess the ability to differentiate between just cows (Coulon

et al., 2009 as cited in Marino and Allen, 2017) as well as discriminate between cows and other species such as sheep (Marino and Allen, 2017). They also possess a good spatial memory—meaning they can remember where objects are located and how to navigate to them—and thus, are good at maze tests (Marino and Allen, 2017). In one study utilizing a maze, they actually performed better than pigs, goats, sheep, and dogs (Kilgour, 1981 as cited in Marino and Allen, 2017). Another study showed that cows can also remember the association between a visual cue and food reward for at least a year (Laca, 1998 as cited in Marino and Allen, 2017).

Past Studies

The ability to discriminate is present in many mammals (Fagot, 2000; Matsuzawa, 2001; Zentall & Wasserman, 2006 as cited in Marino and Allen, 2017), such as dogs being able to discriminate between photographs (Range et al., 2008 as cited in Marino and Allen, 2017) and farm animals being able to discriminate between complex objects (Croney et al., 2003; Hemsworth et al., 1996; Tanida & Nagano, 1998 as cited in Marino and Allen, 2017). Currently, it is unknown if cows are able to recognize humans solely based on their faces. Multiple experiments have been performed to test how well cows can differentiate between objects and people, but they contained uncontrolled influential factors. Some of these experiments used maze tests, which have been shown to be effective in terms of heifers being able to successfully navigate them when multiple food locations are involved as well as retain this information for up to eight hours (Marino and Allen, 2017).

An experiment involving the differentiation between black disks by Holstein bulls resulted in the bulls being able to successfully differentiate between the two disks, but it became more difficult when the disk's surface area differed by a factor less than 4 (Rehkämper and Görlach, 1997). In terms of experiments involving the differentiation between humans, comparisons between negative and positive treatments (Munksgaard et al., 1997; Rushen et al., 1999; Munksgaard et al., 1999) as well as familiar and unfamiliar people (Boivin et al., 1997; Taylor and Davis, 1998) were made. Studies comparing negative and positive treatments found that cows could differentiate between people not based on their clothing (Boivin et al., 1997; Munksgaard et al., 1999). One study in particular found that cows produced less milk due to their heart rates rising when the negative handler was present (Rushen et al., 1999). However, one study found that cows could not differentiate between positive and negative handlers when wearing the same blue overalls, but this may be due to the staff that took care of the cows only wearing blue overalls (Munksgaard et al., 1997). When they repeated this exact study in 1999 and changed the color of the overalls to red and yellow, they found that cows were capable of differentiating between people.

Studies comparing familiar and unfamiliar people found that calves are more likely to approach familiar people (Boivin et al., 1997) and cows can remember which person provides them with a food reward (Taylor and Davis, 1997). Specifically, in Boivin et al.'s study, they found that the calves also spent more time by the feeding bucket with the familiar person than the unfamiliar one, without a significant difference being seen whether the clothing was or was not familiar. Additionally, the calves that were raised with minimal contact more quickly allowed familiar people to touch their

heads than unfamiliar people while the calves that were raised with extensive contact demonstrated no difference when allowing familiar and unfamiliar people to touch their heads. The calves raised with extensive contact demonstrating no preference for familiar or unfamiliar people touching their heads may have reacted this way due to physical touch already being a positive association for them. In Taylor and Davis's study, they used a reinforced nose press response from a specific handler, who was unfamiliar at the start of testing. The nose press response was when the handler would give the cows a food reward if they pressed their nose into the person's closed fist. The cows exhibited orientation towards the now-familiar handler and looked away from the unfamiliar one due to their expectation of a food reward that had been associated. Both handlers were almost identical in height, wore identical clothing and boots, and used all of the same hygienic products to reduce any other different indicators the cows could have used to differentiate between them.

Additionally, a study that is similar to the one performed for this honors thesis, tested how well heifers could differentiate between 2-D images of heifer heads. They found that heifers are capable of successfully discriminating between the heifer heads and they were more likely to approach the familiar heads than the unfamiliar ones (Coulon et al., 2010). Another similar study tested how well cows could differentiate between people that were physically standing in front of them while trying to control any influential factors such as height or clothing (Rybarczyk et al., 2001). This study found that cows are capable of differentiating between people that were wearing the same color clothing. It was also found that cows could discriminate between people with their faces covered if their heights were drastically different. When the people's heights were the same, the

cows could differentiate between the two when their faces were uncovered, but not while their faces were covered with identical masks. However, when the bodies were covered and only the faces were left visible, the cows had more difficulty differentiating between them. Three out of the eight cows got eight out of ten trials correct in one session, but none were able to do this in two consecutive sessions (Rybarczyk et al., 2001). It is believed that cows have difficulty performing this task because they have never seen a human head by itself instead of attached to a body, so their stored visual images do not match what they are seeing (Grandin, 1999 as cited in Rybarczyk et al., 2001). My hypothesis for the following thesis experiment was that Holstein heifers are capable of differentiating between humans solely based on facial features.

METHODOLOGY

The Physical Setup

Six heifers of similar age of twenty-two to twenty-four months were chosen from the University of Maine's Witter Farm. Their names were Bairn, Rampart, Madeline, Dasahlia, Ninja, and Riley. These heifers were chosen based on if they took chocolate from my hand and ate it prior to the experiment. The names of those that took the chocolate and continued to come back for more were selected for testing. Each heifer performed ten trials per day for four days a week for a duration of five weeks. The experiment was designed as a reward system using a Y-maze setup, with two identical black rubber bowls on two identical chairs separated by a metal gate. The pictures being used for differentiation were laminated and clipped to the tops of both chairs. The Y maze was fairly small and a tight fit for the heifers, which allowed the heifers to be more easily controlled and not injure anyone involved in the experimental process. The heifers were released into the Y maze approximately ten feet away from the pictures to ensure they could still see the images while maintaining a far enough distance to be able to make a clear choice of which side to go towards. They received approximately half a cup of sweet calf grain from the bowl if they went to the correct picture, which was determined to be the Caucasian face during Week 1. The calf grain was FCI 20% CP calf starter with rumensin. The pictures of the human faces were those of my friends who have never visited the farm or have ever been in contact with the cows.

A total of four pictures were used over the five weeks: an all-white picture, a sliced tree trunk, an African American human face, and a Caucasian human face.

Initially, both of these chosen faces were going to be the rewarders while six other faces were going to be the non-rewarders, but the heifers struggled with recognizing the first face being used during the training week, which happened to be the Caucasian face. So, it was decided that the African American face would be introduced afterwards as the non-rewarder instead to limit the number of human faces to just two. Additionally, it was believed that these two faces had features that were different enough to be more easily differentiated by the heifers. All of the pictures were the same size and had white backgrounds that were the same shade. The pictures of the faces were 10.5 inches tall and 7.25 inches wide while the picture of the sliced tree trunk was 8 inches tall and 8.5 inches wide. The blank white picture used was one of the other unused pictures that was flipped over so that it was the same size and shade of white as the other pictures.

Using a random number generator, the pictures were randomly assigned to a side. For this particular experiment, the number one was assigned as the left side and the number two was assigned as the right side. The total number of sides ended up being almost exactly 50% left and 50% right, with 596 total left sides and 594 total right sides.

All of the pictures were laminated since the heifers are very messy, but it was ensured that they were not too reflective when the handheld light was shining on them since that could negatively impact the results if the heifers were unable to clearly see the pictures. Starting during Week 2, a small handheld light was shone on the Caucasian face to help the heifers focus on the pictures themselves during some of the trials. This light was used to illuminate the rewarder's face and if they were continuously making correct choices, the light would be taken away to see how they would perform without it. This light was a small, black, square-shaped handheld light that was propped behind the

designated feed bowl so that the heifers could not see the light source, but they were able to see the bright white light on the rewarder's face. In general, the light was used for all ten of the heifers' trials during Week 2. It was then reduced to being used for the first five trials for each heifer per day for the rest of the following weeks.

Week 1 was the training week using the all-white picture and Caucasian face, where it was determined that the heifers preferred calf grain over chocolate. After Week 1, calf grain was consistently used as the food reward because not only did the heifers prefer it more, but it also cost a lot less. The purpose of comparing the blank photo to the photo of the Caucasian face was to establish shape recognition in the heifers. Week 2 used the pictures of the sliced tree trunk and Caucasian face to ensure that the heifers responded to the correct object image and its similar shape and color encouraged the heifers to focus on the individual features rather than basic shapes. Lastly, Weeks 3 through 5 used the pictures of the Caucasian and African American faces to test how well the heifers focused on the facial details. Week 5 was performed around six weeks after Week 4 was performed in order to assess the information they retained.



Figure 1. Y-maze Setup: The Y-maze setup made of connecting metal gates. The chairs with the images clipped at the top and the metal fence divider are pictured.

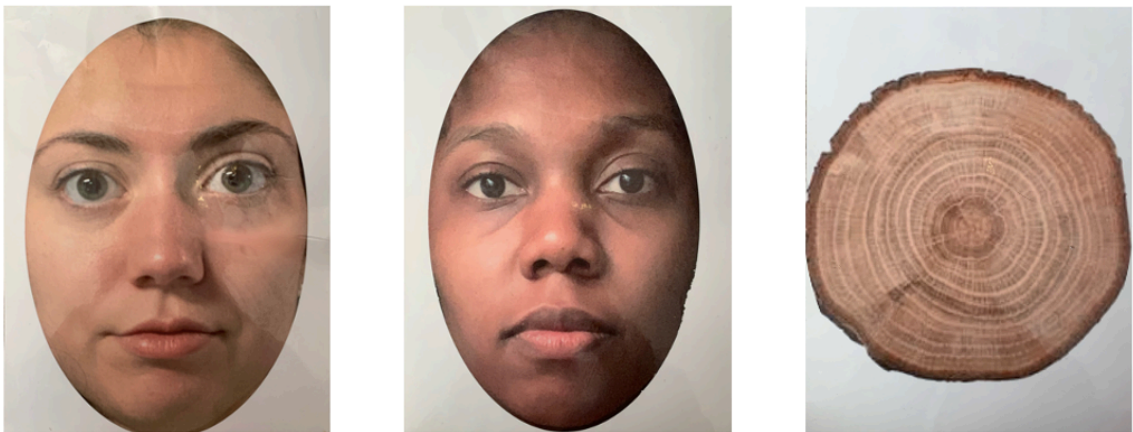


Figure 2. Pictures: The image on the left is the Caucasian face, the image in the middle is the African American face, and the image on the right is the sliced tree trunk.

Determining Choices

The heifers were given thirty seconds to make a choice, but Ninja was given longer due to her being more easily distracted and thoroughly grooming herself before making a decision. A choice would be counted when a heifer stuck her face in one of the bowls. Occasionally, some of the heifers would try to outsmart the system by finding an alternative way of receiving the food reward without using the faces whatsoever, which required close observation when classifying if the choice was considered to be correct. This alternative way was discovered by Ninja and Bairn, and it involved them trying to look inside both bowls to see which one had the food reward in it before deciding which side to choose. If the heifer was standing in front of the divider and initially leaning far over to the correct side and only glanced at the incorrect side while putting her face towards the correct bowl, it was counted as a correct choice. If the heifer was standing in front of the divider and initially leaning over to the incorrect side, but clearly looked inside the other side's bowl before switching sides, it was counted as an incorrect choice.

The methodology was then adapted by having the grain pushed up against the front of the bowl closest to the heifers and adding a couple grain pieces in the back so that both bowls looked like they had a food reward in them without the heifers being able to confirm unless their heads were directly over a bowl. This greatly reduced the prevalence of this unwanted alternative method, but it is unknown if it was able to completely eliminate it for the remainder of the experimentation period.

Data Analysis

All of the results were organized and analyzed by IBM SPSS statistical software, which is a computer program that performs advanced statistical analysis on the desired data. This software was used to create all of the graphs and it calculated the associated p values using Chi square procedures. A p value calculated using Chi square procedures is the number that describes how likely the data could have occurred if the null hypothesis was true (Bevans, 2021). For example, a p value of .05 means that there is a 5% chance that the data could have occurred if the null hypothesis was true. For this study, the null hypothesis would be that Holstein heifers are not capable of differentiating between solely human faces. Additionally, the success rates were calculated using Microsoft Excel functions.

RESULTS

Combined Data

When looking at the heifers' overall progress, there was a significant improvement in the number of correct choices made for a total of 1,190 trials as the weeks progressed. During Week 1, the heifers achieved an overall success rate of 53.9% and by Week 5, they achieved an overall success rate of 67.8%. Although, one heifer—Rampart—was not included for Day 1 of Week 1 because she refused to eat the reward and refused to make any decisions. If she had gotten all 10 trials correct—which would be highly unlikely—the overall success rate of Week 1 would have been 58.3%, which would be around 10% less than the overall success rate of Week 5. Figure 3 below shows a general increasing trend as the weeks progress in terms of the number of correct trials increasing and thus, the success rates as well.

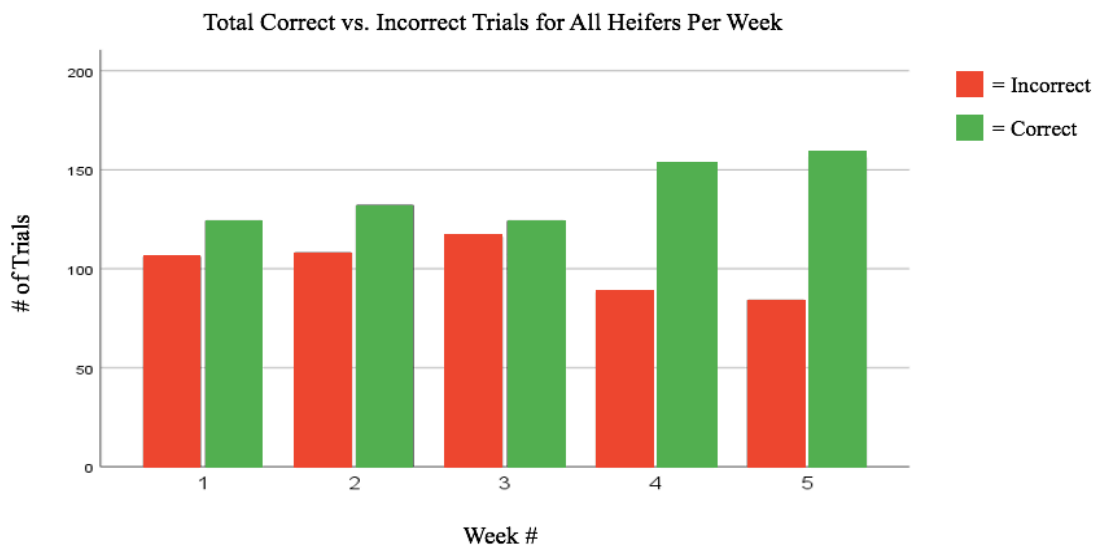


Figure 3. Total Correct vs. Incorrect Trials for All Heifers Per Week: Total number of correct and incorrect trials for all of the heifers combined for each of the five weeks. Significance is indicated by a Chi square test, $\chi^2 (4, N = 1190) = 14, p = .007$.

Before the portable light was used to illuminate the rewarder's face, the heifers achieved an overall 53.9% success rate during Week 1 without Rampart's Day 1 results and around 55% success rate during Week 5. There is no general trend seen in Figure 4 since the success rates for each week were all around 50% without the use of the light.

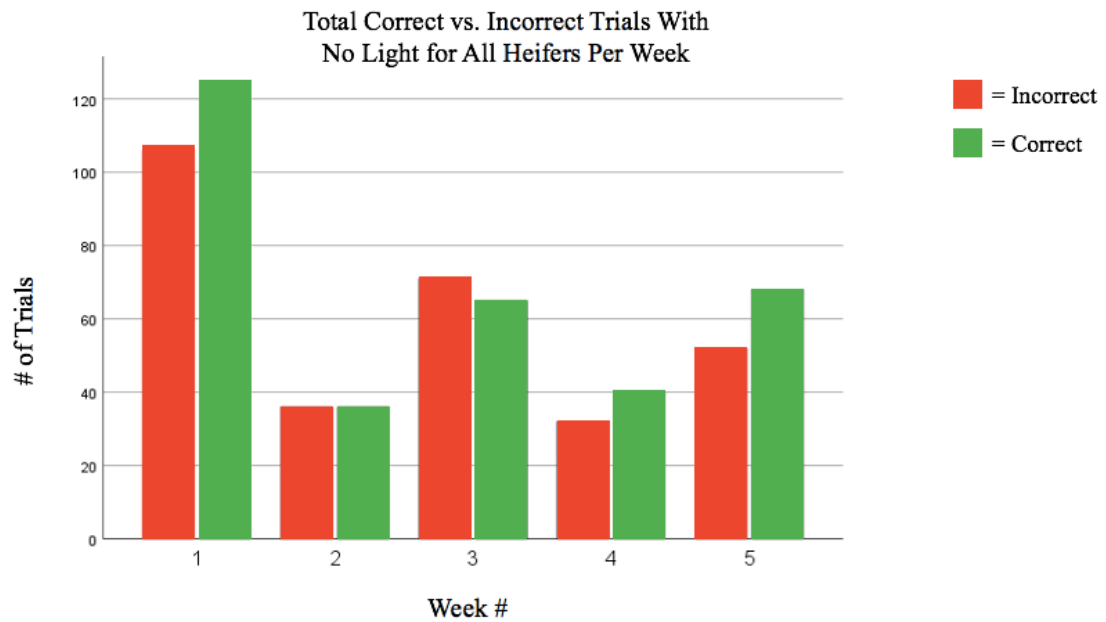


Figure 4. Total Correct vs. Incorrect Trials Without Light Per Week: Total number of correct and incorrect trials for all of the heifers combined per week without the light illuminating the rewarder's face. No significance is indicated by a Chi square test, $\chi^2 (4, N = 630) = 2.6, p = .62$.

When the portable light was introduced and used to illuminate the rewarder's face, the number of correct trials compared to incorrect trials generally increased as the weeks progressed, demonstrated in Figure 5 below. The heifers ended up achieving an overall 73.3% success rate for Week 5, which is about 15% higher than the success rate during Week 2.

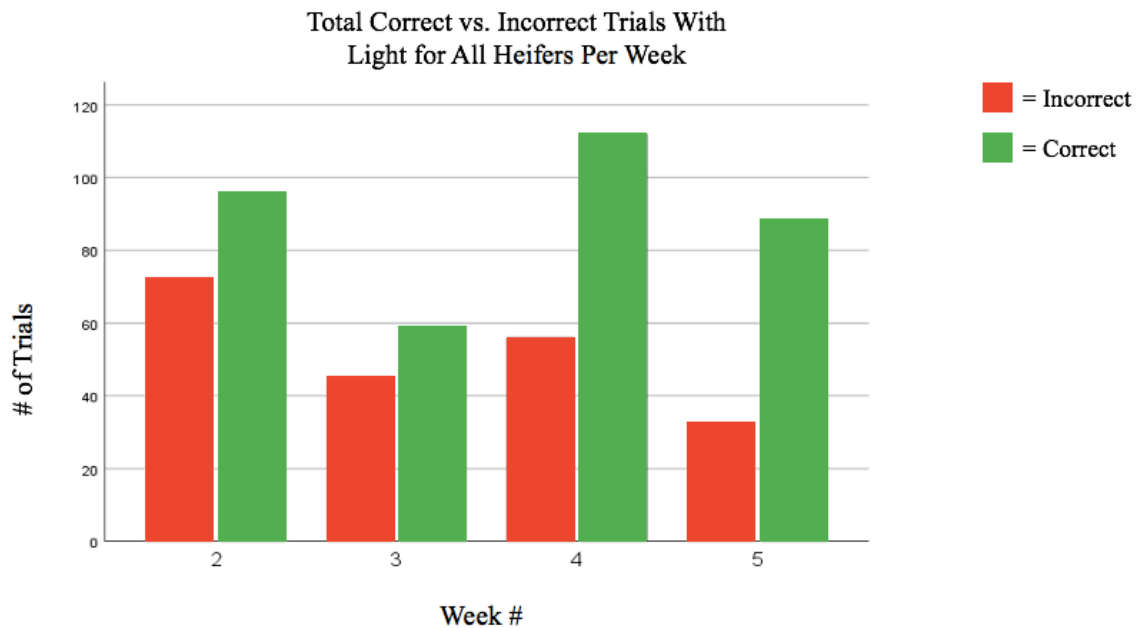


Figure 5. Total Correct vs. Incorrect Trials With Light Per Week: Total number of correct and incorrect trials for all of the heifers combined per week without the light illuminating the rewarder's face. Significance is indicated by a Chi square test, $\chi^2 (3, N = 560) = 10.7, p = .013$.

Individual Data

Bairn achieved the most significant success rate while utilizing the light and Ninja achieved the most consistent high success rates overall. Dasahlia and Madeline were the only heifers that demonstrated no improvement by the final week, with the use of the light making almost no difference.

During Week 1, Bairn achieved a 42.5% success rate and during Week 4, she achieved a 72.5% success rate. She then achieved a 77.5% success rate during Week 5, with almost twice the number of correct trials by the end. Generally, Figure 6 below shows an increase in the number of correct compared to incorrect trials as the weeks progressed. Major improvement for Bairn can be seen during Week 2 when the portable light was first introduced, where she achieved a 70% success rate. Without the light, Bairn achieved an overall success rate of 52.4%. In comparison, she achieved an overall success rate of 82.1% with the light being present, which is the highest success rate involving the light. The calculated p value when comparing light versus no light is $<.001$, indicating high significance.

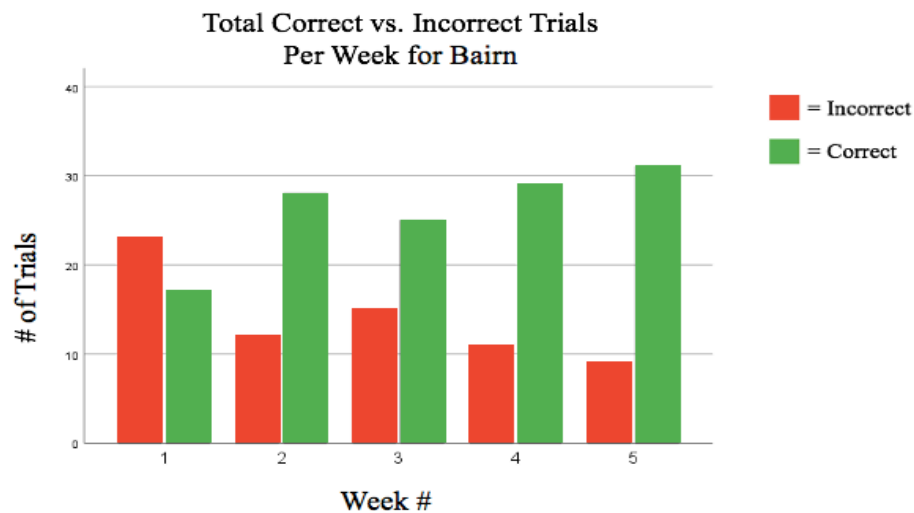


Figure 6. Total Correct vs. Incorrect Trials Per Week for Bairn: Total number of correct and incorrect trials each week for Bairn. High significance for the last three weeks of testing is indicated by a Chi square test, $\chi^2 (4, N = 200) = 13.2, p < .001$.

Rampart achieved a 60% success rate for both Weeks 1 and 4. Although, her Day 1 results of Week 1 are not included due to her refusing to make any choices. She then achieved a 70% success rate during Week 5. Excluding Week 2 as the outlier, there is a general increase in the number of correct versus incorrect trials as the weeks progress depicted in Figure 7 below. When the portable light was introduced, Rampart achieved an overall success rate of 63% compared to the success rate of 53.1% she had achieved without utilizing the light. The calculated p value when comparing light versus no light is .16, indicating no significance.

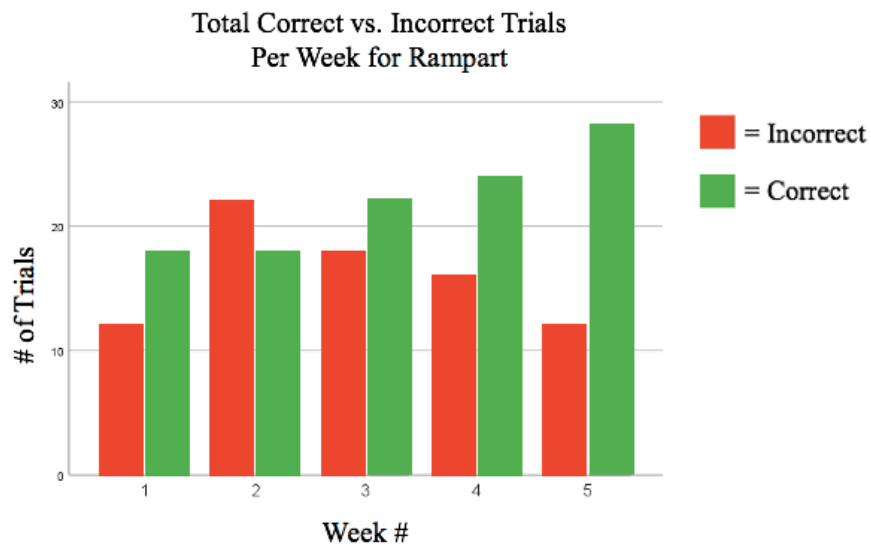


Figure 7. Total Correct vs. Incorrect Trials Per Week for Rampart: Total number of correct and incorrect trials each week for Rampart. Significance for the last three weeks of testing is indicated by a Chi square test, $\chi^2 (4, N = 190) = 5.4, p < .007$.

During Week 1, Madeline achieved a 55% success rate and during Week 4, she achieved a 60% success rate. She then achieved a 52.5% success rate during Week 5. When the light was utilized, her success rate was 54.6% compared to the 46.7% success rate without the light. The calculated p value when comparing the light versus no light was .20, indicating no significance. Madeline consistently had more correct than incorrect trials throughout the weeks, with only Week 3 in particular having significantly more incorrect than correct trials, acting as an outlier. Although, there is no general trend in the number of correct versus incorrect trials as the weeks progress, which is depicted in Figure 8 below.

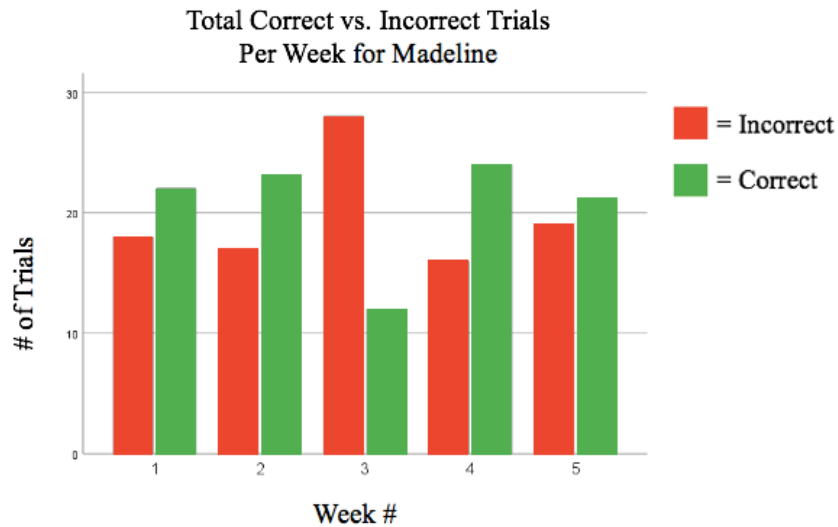


Figure 8. Total Correct vs. Incorrect Trials Per Week for Madeline: Total number of correct and incorrect trials each week for Madeline. No significance for the last three weeks of testing is indicated by a Chi square test, $\chi^2 (4, N = 200) = 9.3, p = .74$.

During both Weeks 1 and 5, Dasahlia achieved a 55% success rate. For Week 4, she had achieved a 45% success rate. There is no general trend depicted in Figure 9 below for the number of correct versus incorrect trials as the weeks progressed because her success rates rarely varied. Her success rate while the light was being used was 48.6% compared to her success rate of 51.6% when the light was not being used. The calculated p value when comparing the light versus no light was .67, indicating no significance.

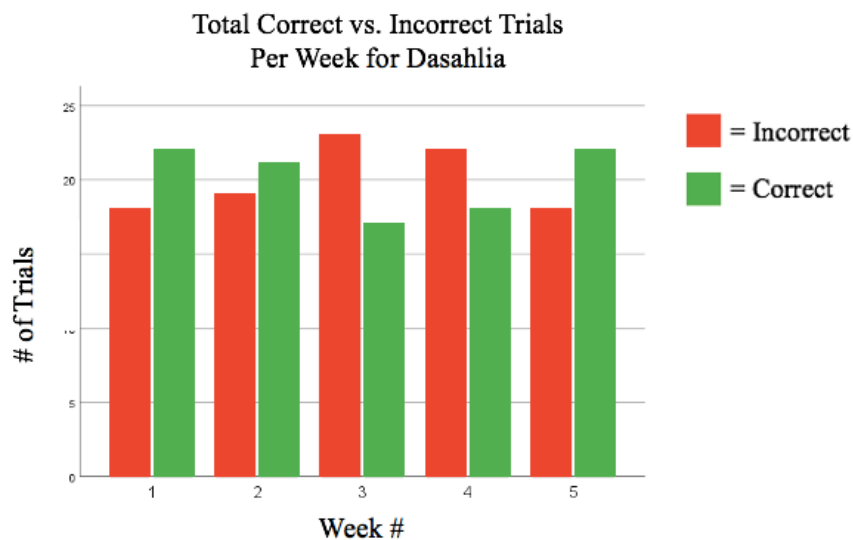


Figure 9. Total Correct vs. Incorrect Trials Per Week for Dasahlia: Total number of correct and incorrect trials each week for Dasahlia. No significance for the last three weeks of testing is indicated by a Chi square test, $\chi^2 (4, N = 200) = 2.2, p = .74$.

During Weeks 1 and 4, Ninja achieved a success rate of 62.5%. She then achieved an 80% success rate during Week 5. Figure 10 below depicts a general increasing trend of the number of correct trials as the weeks progressed, with the final week having the highest success rate. While the light was being used, her success rate was 66% compared to her similar success rate of 65.7% when the light was not in use. The calculated p value when comparing the light versus no light was .90, indicating no significance.

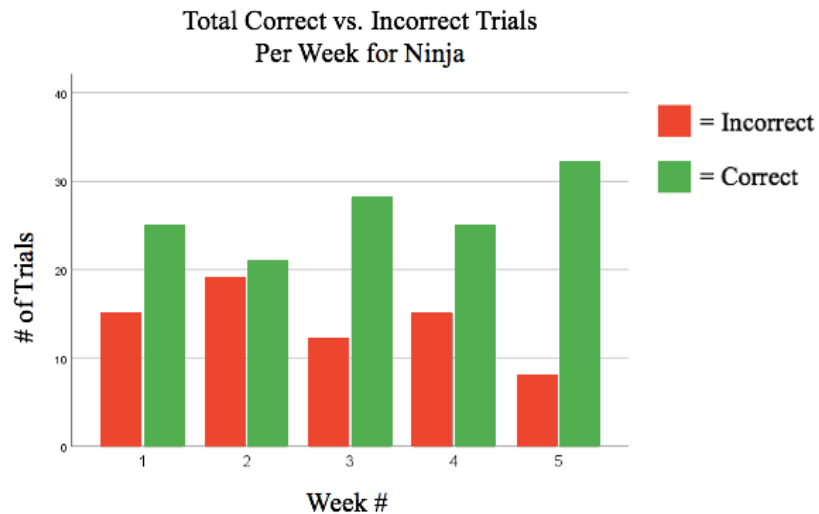


Figure 10. Total Correct vs. Incorrect Trials Per Week for Ninja: Total number of correct and incorrect trials each week for Ninja. High significance for the last three weeks of testing is indicated by a Chi square test, $\chi^2(4, N = 200) = 7.4, p < .001$.

During Week 1, Riley achieved a 50% success rate and during Week 4, she achieved an 80% success rate. She then achieved a 55% success rate during Week 5. No general trend is depicted in Figure 11 below, but Week 4 can be visualized as the outlier compared to the other weeks. The outlier is Week 4 because Riley consistently achieved around a 50% success rate during every other week. Her success rate when utilizing the light was 68.1% in comparison to her success rate of 48.1% when not utilizing the light. The calculated p value when comparing the light versus no light was .004, indicating significance.

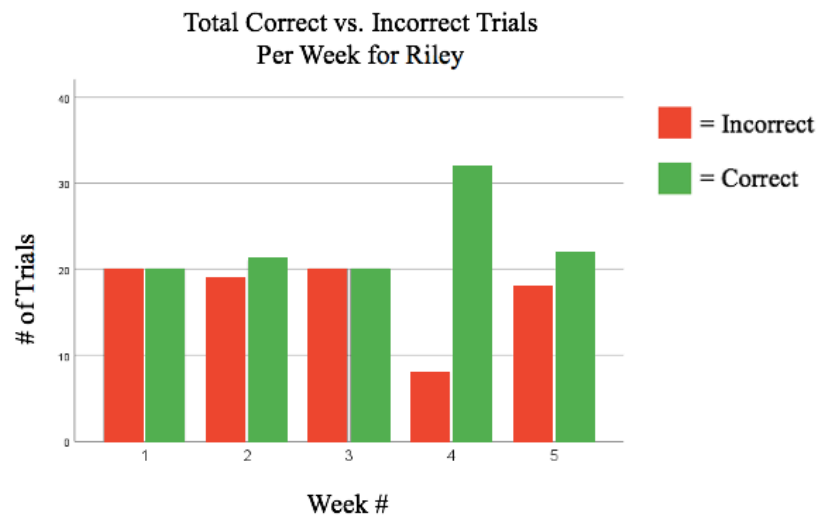


Figure 11. Total Correct vs. Incorrect Trials Per Week for Riley: Total number of correct and incorrect trials each week for Riley. Significance for the last three weeks of testing is indicated by a Chi square test, $\chi^2(4, N = 200) = 10.6, p = .031$.

All of the heifers had a side preference except for Dasahlia. Bairn and Ninja had slight preferences for the right side, Madeline had a significant preference for the left side, Rampart had a significant preference for the right side, and Riley had a moderate preference for the left side. For the heifers with side preferences, they were more likely to go to either the left or the right side more than the other one every trial. Certain heifers had stronger preferences towards a side and chose that side much more often, which was reinforced if the first few trials happened to consecutively have the rewarder on the same side. This caused the heifers to expect the food reward to still be on that side since it had been every time for the past few trials.

DISCUSSION & CONCLUSIONS

When looking at the combined data for the heifers, significance is indicated when comparing the number of correct versus incorrect trials when using the light, $\chi^2 (3, N = 560) = 10.7, p = .013$. This demonstrates the effectiveness of the light illuminating the rewarder's face since the heifers were very responsive to it. Conversely, the comparison between the number of correct and incorrect trials when the light was not in use indicated no significance, $\chi^2 (4, N = 630) = 2.6, p = .62$. This supports the finding that the light improved the number of correct trials for the heifers and without the light illuminating the rewarder's face, the heifers were mainly choosing at random. This indicates that the heifers were more focused on the light than the rewarder's face itself.

Bairn's data indicates significance when comparing her total number of correct versus incorrect trials for the last three weeks when both faces were being utilized, $\chi^2 (4, N = 200) = 13.2, p < .001$. Additionally, a general positive trend in the total number of correct trials as the weeks progressed is depicted in Figure 6 above. Thus, her data supports the claim that heifers can recognize people solely based on their faces. She was able to increase her success rate by 30% from Week 1 to Week 4 and then increased her success rate again by 5% during Week 5. This indicates that she was able to retain the information that she had learned and was able to perform it more successfully after a period of six weeks. However, high significance is indicated when comparing the number of correct versus incorrect trials she had with and without the light, with the number of correct trials being significantly higher when the light was in use, $\chi^2 (1, N = 200) = 22.7, p < .001$. The success rates for the number of correct versus incorrect trials were 82.1%

with and 52.4% without the light, which strongly indicates that Bairn was heavily relying on the light illuminating the rewarder's face for receiving the sweet calf grain than observing the actual faces themselves.

Rampart's data when comparing the total number of correct versus incorrect trials for the last three weeks indicating significance and a general increasing trend in the number of correct compared to incorrect trials depicted in Figure 7 above suggest that she was able to learn to identify the rewarder's face, $\chi^2 (4, N = 190) = 5.4, p < .007$. Her success rates for both Weeks 1 and 4 were 60%, but this excludes her Day 1 of Week 1. Her success rate increased to 70% during Week 5, indicating that not only was she able to retain the information that she had learned, but she was able to more successfully perform the task after a period of six weeks. Although no significance was indicated when comparing the number of correct versus incorrect trials with and without the light, there were 10% more correct trials when the light was being utilized, $\chi^2 (1, N = 190) = 1.9, p = .16$. This indicates that she was more focused when the light was present, but not enough to be considered a significant difference.

Madeline's data when comparing the number of correct versus incorrect trials per week for the last three weeks was insignificant, $\chi^2 (4, N = 200) = 9.3, p = .74$. Although, it can be noted that Week 3 is an outlier with a much higher number of incorrect than correct trials compared to the other weeks. If this outlier was excluded, her data would still indicate little improvement, even with there being a higher number of correct than incorrect trials every week. Her success rate from Week 1 increased from 55% to 60% during Week 4, but it decreased to 52.5% during Week 5. This indicates that she was somewhat able to learn the task, but that she was unable to retain the information in order

to successfully perform it after a period of six weeks. Her data when comparing the number of correct versus incorrect trials with and without the light was also insignificant, with around 8% more correct trials while the light was being used, $\chi^2 (1, N = 200) = 1.66, p = .20$. Thus, this indicates that the light was not a major factor in Madeline's decision-making process. For the most part, she ran immediately to one of the faces without taking time to examine both options first. It is unknown whether or not she was processing the photos of the faces, but her data indicates that she was not focused on differentiating between the faces since her success rates usually remained around 50%.

Dasahlia was the only heifer to not demonstrate any progress whatsoever. No significance is indicated in her data for the total number of correct and incorrect trials per week, $\chi^2 (4, N = 200) = 2.2, p = .74$. Additionally, no significance is indicated in her data for the total number of correct and incorrect trials when the light was or was not being utilized, $\chi^2 (1, N = 200) = 0.18, p = .67$. This demonstrates that she was unable to successfully learn this task and continued to randomly guess sides rather than attempt to figure it out. Both Weeks 1 and 5 had a 55% success rate, demonstrating the lack of improvement and to take it one step further, her Week 4 success rate was even lower at 45%. Furthermore, she had a 48.6% success rate with the light in comparison to a 51.6% success rate without the light, which indicates that she was not focused on the light at all. Dasahlia had a quick temper, so she would easily become frustrated if she was not choosing correctly, resulting in her rushing the process instead of thinking it through.

Ninja performed the overall best out of the participating heifers. Her data for the total number of correct and incorrect trials per week for the last three weeks indicated a general positive trend in the number of correct trials per week and high significance, χ^2

(4, N = 200) = 7.4, $p < .001$. Although, Week 2 was an outlier since the success rate was a little over 50%. Additionally, her data when comparing light versus no light indicated no significance, which demonstrates that she did not need the light in order to perform the task successfully, $\chi^2 (1, N = 200) = 0.02$, $p = .90$. Her success rates for using the light versus not using the light were almost identical, further supporting the previous claim that she was just as successful without the light than with it. Although the success rates when comparing the total number of correct and incorrect trials were identical at 62.5% for Weeks 1 and 4, she achieved around a 70% success rate during Week 3 in addition to an 80% success rate during Week 5. Therefore, she demonstrated significant improvement in successfully learning the task and was able to not only retain the information, but better utilize it after a period of approximately six weeks.

Lastly, Riley's data for the total number of correct and incorrect trials per week indicated significance, $\chi^2 (4, N = 200) = 10.6$, $p = .031$. Additionally, significance was indicated for the total number of correct and incorrect trials when the light was or was not utilized, $\chi^2 (1, N = 200) = 8.13$, $p = .004$. This suggests that she was able to successfully learn the task and that she was able to perform more successfully when the light was being utilized. The data supports that Riley was more successful with the light because her success rate was 68.1% compared to the 48.1% without the light. On the other hand, the data does not fully support that Riley was able to successfully learn the task because of Week 4 acting as the outlier. She achieved a 50% success rate during Week 1 and a 55% success rate during Week 5, but her success rate skyrocketed to 80% during Week 4. For every other week, she achieved around a 50% success rate, so Week 4 was the only week that she performed extraordinarily. She may have been more focused during Week

4 than during the other weeks, which resulted in her high success rate. Additionally, the success rate for Week 5 declining from Week 4's success rate demonstrates that Riley was able to retain some of the information, but she was unable to successfully perform the task as well as she had six weeks prior.

The overall training procedure proved to be successful since all of the heifers were able to successfully learn the concept of the Y maze and four out of the six heifers were able to perform the task successfully. All of the heifers were able to learn that one of the bowls had a food reward in it and if they chose the correct side of the Y maze, they would receive it and if they did not choose correctly, they would have to try again. Every heifer would enthusiastically move towards a bowl for each trial and they maintained this same level of enthusiasm for all ten trials every day, indicating that they would still be very willing to perform the task if there were more than ten trials required. The heifers were also tested in the same order every day, so they had memorized this after the first week or so and would already be waiting in front of the gate when it was their turn to be retrieved for testing. Although, a separate training period should be utilized if this experiment were to be repeated because it would increase the accuracy of the results since the heifers in this particular experiment were only given one training week where the data was included in the analysis for the final results. As for performing the general task, four out of the six heifers were able to successfully perform the task and their data was able to indicate their success. The procedure utilizing the light was also successful, but most of the heifers struggled without the light being used as an indicator. The presence of the light generally improved the success rates for the heifers and the data demonstrates that light is not only a strong indicator, but it is the preferred indicator over

facial details. This is most likely due to the light's simplicity requiring little focus in comparison to the more intense focus required for observing more minute differences between faces.

Overall, three out of the six heifers—or 50% of the total participating heifers—were able to retain the information that they had learned regarding the task after a six-week period of no testing and five out of the six—or 83.3% of the total participating heifers—were able to successfully learn the task prior to the six-week period of no testing. In a similar study observing memory in fifteen-month-old Holstein heifers compared to cows, it was found that out of thirteen participating heifers, 46% of them were able to successfully remember the task after a six-week period of no testing and 92% of them were able to learn the task prior to the six-week period (Kovalchik & Kovalchik, 1986). This study was also using a feed reward system, so my results support both of this study's findings. In a study observing how cows use different body and facial cues to discriminate between humans, it was found that when only the face was visible, three of the eight Holstein cows achieved an 80% success rate out of ten total trials in one session, but none were able to achieve this success rate in two consecutive sessions. My results contradict this finding because Ninja was able to achieve an 80% success rate for the first two days of Week 5 and then achieved a 90% success rate for the third day of Week 5. So, she was able to achieve a success rate of at least 80% for three sessions or days in a row. She was also able to achieve an 80% success rate for the first two days of Week 1 and then again for three sessions in a row, which were the last two days of Week 3 and the first day of Week 4. Additionally, Bairn was able to achieve an 80% success rate for three sessions in a row, which were the last two days of Week 2 and the first day of Week

3. Therefore, my results show that two out of the six participating heifers were able to achieve at least an 80% success rate in two or more consecutive sessions.

A major factor that affected the accuracy of the results was that Ninja and Bairn learned an alternative method to receive the food reward that did not require them to focus on the faces. Ninja was able to figure this out first and Bairn attempted to do the same starting the week after Ninja did. Bairn was very obvious, but it was more difficult to catch Ninja doing it. Another factor that affected the accuracy of the results was that almost every heifer had a side preference. The three heifers with stronger preferences—Madeline, Rampart, and Riley—were more focused on the side location than the pictures. Specifically, Madeline's and Riley's poor performances could be due to their stronger preferences for the left side since they were more focused on running to get the food reward on that side than using the pictures to figure out the task. When they guessed the left side correctly and received the food reward, this reinforced their behavior and encouraged them to not focus as much on the task they were supposed to learn. Meanwhile, Ninja and Bairn only had a slight preference for the right side, which further supports the claim that they were successfully learning the task rather than just guessing. Although, Dasahlia performed the worst out of all the heifers and she was the only one that did not have a side preference. This strongly supports that she was completely guessing for every trial and thus, she was not using any sort of indicators as to which side she should be choosing. Cows have no inherent side preferences as a species, but they each may individually favor a specific side (Tucker et al., 2009). A third factor that negatively impacted the results was that the barn used as the location to test the heifers had too many distractions such as people, horses, and birds. This would completely ruin

the heifers' focus and thought process when attempting to perform the task. The last factor that negatively impacted the results was that the picture of the sliced tree trunk used during Week 2's testing was too similar to the picture of the rewarder's face. The tree trunk was a similar shape and color to the rewarder's face, so this may have partially confused the heifers and prevented them from being able to clearly understand what picture they should have been going to. The purpose of Week 2 was to teach the heifers to choose the human face over any object, but this may have not been fully accomplished since the face and object were very similar.

From this experiment, it can be concluded that Holstein heifers may be capable of differentiating between human faces solely based on facial features, but this greatly varies from heifer to heifer depending on their individual levels of focus. Overall, the data was not significant when looking at the number of correct versus incorrect trials without the light, but it was significant when the light was in use. Although it was not the original intent of the study, it can be concluded that Holstein heifers can respond to light cues. Thus, Holstein heifers do not generally differentiate between people based off of their faces alone due to them having other preferred indicators, but Ninja in particular demonstrated that it is possible for them to identify human faces without any other indicators. More studies are needed in order to result in a solidified conclusion because this particular study only resulted in one out of six heifers being able to fully support the hypothesis. It can also be concluded that Holstein heifers are able to retain information they have learned after a six-week period of not using that information. Although, this also varies from heifer to heifer depending on how good their memories are since every cow is different.

The results of this experiment stress the importance of proper handling regarding cattle. If heifers are capable of recognizing faces, especially after a period of six weeks, improper handling can negatively impact them in the future. Previous studies have shown how improper handling has contributed to poor milk production among other issues due to the recognition of the negatively associated handler. Specifically, meat quality would improve if the animal is less stressed. A normal, relaxed animal converts their muscle glycogen into lactic acid, which is what gives meat its great taste and quality. When an animal is stressed, their adrenaline uses up this glycogen, which prevents enough lactic acid from being produced and thus, the meat quality and good taste decrease (Zimmerman, 2015). Hopefully, other researchers will expand on this experiment to contribute more to the topic because not much research has been done regarding it. Little research has been done with farm animals in order to maximize agricultural production (Bang, 2018) because people find it easier to care less about animals by believing that they are unintelligent and have no personality or emotions. With more research, enough information could be compiled that could help improve the dairy industry as a whole. A better understanding of cattle will allow improvements to be made to all cattle industries, which will result in not only happier cows, but better producing ones.

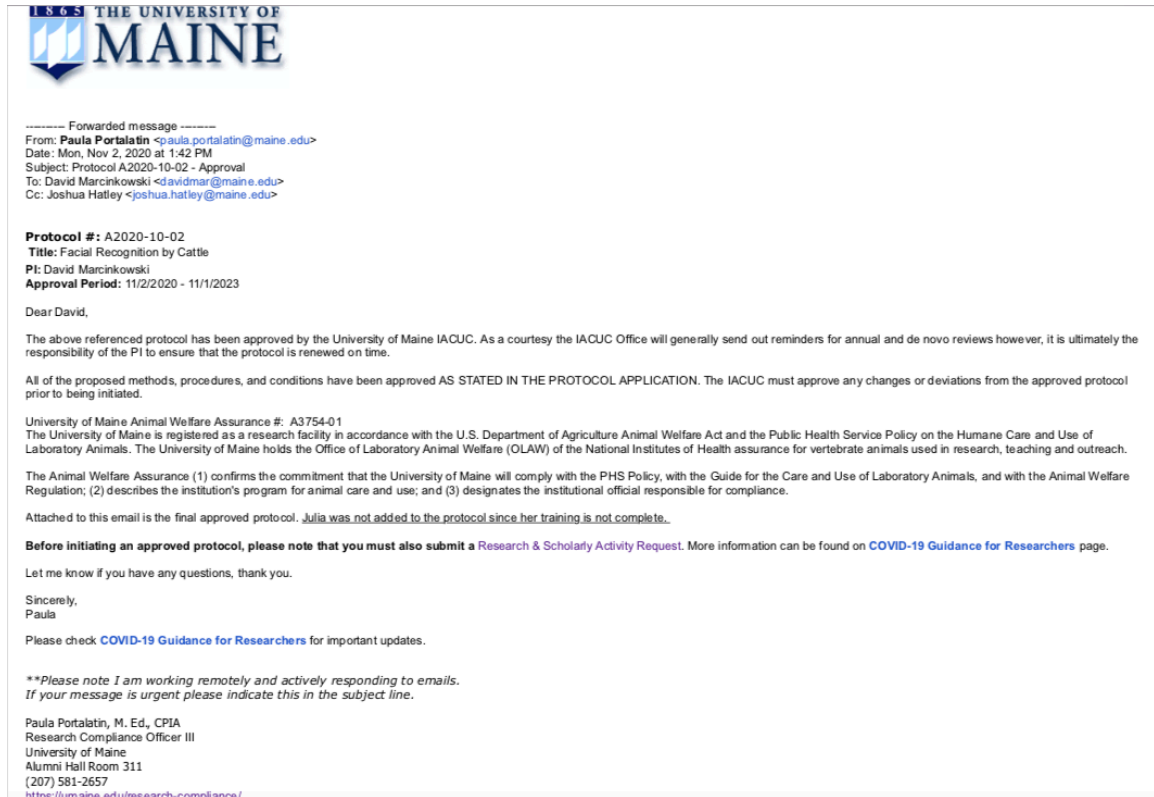
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APPENDIX

Copy of Institutional Animal Care and Use Committee (IACUC) Approval Email



AUTHOR'S BIOGRAPHY

Kendra L. Huth was born in Beverly, Massachusetts on December 9, 1998. She graduated from Beverly High School in 2017 and went to the University of Maine to major in animal and veterinary sciences. Additionally, she has a concentration in pre-veterinary medicine and a minor in zoology. She was a hard worker at her campus's dining hall for all four years of her college experience and she enjoys making people smile. After graduation, Kendra hopes to find a career in animal research regarding endangered species.